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The influence of water-drinking with meals upon the digestion and utilization of proteins, fats, and carbohydrates

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THE INFLUENCE OF WATER-DRINKING WITH MEALS UPON THE DIGESTION AND UTILIZATION OF PROTEINS, FATS, AND CARBOHYDRATES

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The Influence of Water-Drinking with Meals upon the Digestion and Utilization of Proteins, Fats and Carbohydrates.

Introduction.

Current Theories. Notwithstanding the fact that many persons are accustomed to drinking considerable amounts of water with their meals, and with no apparent ill effect, the opinion has been and still is somewhat general, and the statement almost axiomatic, that the use of water with meals is injurious and harmful. The arguments advanced in proof of this statement are typical of that quasi-scientific reasoning which assumes, a priori, the truth of certain antecedents; the consequents must therefore logically be true.

A concrete statement of the views as generally held by the medical profession and, through them, by the general public, may be cited from Carrington 1) .

"We can lay down the definite and certain rule that it (water) "should never be drunk at meals, and preferably not for at least one hour after the meal has been eaten. The effect of drinking

"water while eating is, first, to artificially moisten the food, "thus hindering the normal and healthful flow of saliva and the "other digestive juices; secondly, to dilute the various juices to an abnormal extent;,and thirdly, to wash the food elements "through the stomach and into the intestines before they have had "time to become thoroughly liquefied and digested. The effects "of this upon the welfare of the whole organism can only be "described as direful."

It needs no argument to prove that such effects upon the organism are direful, but the proof that such effects follow the drinking of water with meals is entirely wanting. On the contrary, experiments have been made which show specifically that certain of these effects do not follow.

The contentions put forth in the above quotation are general, and may be grouped under three headings: (1) an artificial moistening of the food hinders the normal flow of the saliva and the other digestive juices; (2) the various juices are diluted to an abnormal extent and are therefore less efficient; (3) the food elements are washed through the stomach and into the intestine before they are thoroughly liquefied and digested.

Although no experimental evidence substantiates the statement it will be granted at the start, that any circumstance that induces insufficient mastication of the food before swallowing is undesirable, the reason being that the movements of the alimentary tract are insufficient to bring about the necessary fineness of division of the food particles. Therefore in all the discussion and experimental work that follows, water with meals means the taking of water when the mouth is empty; the food is masticated as usual,

without the aid of water; water is never used to wash down the products of incomplete mastication.

The Effect of Water on the Digestive Juices. The degree of dryness of the food determines the amount of saliva poured out upon it, the drier the food, the larger the amount of saliva that is secreted 2). The kind of food introduced into the mouth determines also the physical properties of the saliva. It will be argued, therefore, that the taking of water with food prevents the normal secretion of saliva. In the experiments that follow, however, since water is not mixed with the food while this is in the mouth, the effect of water on the secretion of saliva is only a residual one, that is, an effect due to the presence of whatever water may remain in the mouth after swallowing.

The influence of water upon gastric secretion was first investigated by Pavlov and Chigin 3) and their findings have been confirmed by later investigators, especially by Foster and Lambert 4) . The first mentioned workers in experiments on dogs with Pavlov stomachs and divided vagi showed that water stimulates the flow of gastric juice if comparatively large amounts (400-500 cc) are ingested, but that with small amounts (100-150 cc.) in half the cases observed, not the least trace of secretion could be found. "It is only a prolonged and widely spread contact of the water with the gastric mucous membrane, which gives a constant and positive result." 3) Since the vagi were divided the effect of the water must have been that of a chemical excitant.

The later investigators 4) in experiments on the influence of water when taken with food showed that water causes not only a

more voluminous secretion but also a more acid secretion. They suggest that a physiological basis for the objection to copious water-drinking with meals may be found in the increased activity to which the glands are thus forced. If glandular activity requires as much energy as other forms of activity , this special and excessive secretion may be a form of extravagance leading to weakening and premature death of the cells. In fact, they find that the juice excited by a meal following five or six hours after a meal with water and its greater demands, is less in amount than a normal meal should excite. Whether this is a true gland fatigue, and whether or not such observations point to a premature death of the cells can be determined only by histological examinations.

They also suggest that if there is an automatic control in the stomach, such that the chyme, no matter what its state of dilution, always has the same optimum acid concentration, then the increased acidity noted in the accessory pouch may not actually exist in the stomach proper; here, by dilution, the acid concentration may remain unchanged. If the stimulation of water is entirely a chemical one, however, it is difficult to see why the mucosa of the pouch, which is not in contact with the water, should respond as readily as the stomach itself, even though it has the same nerve and blood supply. Any effect which the accessory pouch shows may be considered to be less marked than the one actually secured in the stomach proper. It seems reasonable to believe, then, that the contents of the stomach proper, though more dilute, are at the same time more acid.

The experiments of Hemmeter 5) are of interest in this connection. He showed that after extirpation of the salivary glands

in a dog no enzymes appeared in the gastric juice; they could not be restored by feeding masticated and insalivated food but only by injections of salivary extracts of normal dogs, and the latter were still effective after the vagi had been cut. The conclusion from these observations that the salivary glands produce a hormone was attacked by Loevenhart and Hooker 6) who could demonstrate no increased flow of gastric juice or higher acidity on injection of such gland extracts into normal dogs. In the light of Hemmeter's experiments if the effect of water in the mouth causes the food to be brought more closely in contact with the nerves which stimulate salivary secretion, then the increased hormone production caused thereby may play a part in the greater flow and increased acidity of the gastric juice that has been observed.

Water also acts as an excitant of pancreatic juice 7). When 150 cc. of water are introduced unnoticed into the stomach of a dog the pancreas begins to secrete, or augments its flow, within a few minutes after the water has entered the stomach. Since this amount of water is insufficient to excite a flow of gastric juice, the secretion of pancreatic juice is not secondary to the other, but is a direct result of the presence of water in the stomach. Acids of all kinds act as powerful excitants of pancreatic secretion. The flooding of the small intestine with larger amounts of acid chyme means an increased production of pancreatic secretin and a consequent increased flow of pancreatic juice. The biliary secretion has also been shown to respond to pancreatic secretin and the digestive properties of the pancreatic juice are augmented in a very marked way by the bile. Hence the increased acidity of the gastric contents causes a much more active digestive juice to be poured out

upon the chyme as it reaches the duodenum.

The effect of water in the intestine has not been demonstrated as clearly as its effect in the middle portion of the alimentary canal. Under ordinary circumstances the intestinal juice is secreted only by those portions of the tube with which the food is in concact 8) . Mechanical stimulation is effective in producing a secretion but it is shown that such secretion is comparatively poor in enzymes and contains only salts and water. When poured out upon food the intestinal juice is rich in enterokinase, but much more powerful stimulants even than food in this regard are the pancreatic enzymes; which one of them is active in this direction is not yet known. Peristalsis is known to increase with the volume of material within the intestine. Whether a large amount of a liquid mass is as efficient in this regard as an equal bulk containing less water is uncertain.

The effect of dilution upon enzyme activity in general should be mentioned. The reactions brought about by enzymes are like all other chemical reactions in that they are reversible. They do not proceed to completion unless the products of the reaction are removed as formed. In a concentrated solution the point at which the reaction comes to a standstill is reached sooner than in a dilute one, and in many instances the equilibrium of a reaction mixture may be disturbed by dilution ; the reaction is forced toward completion if water is added.

In the light of this fact the increased activity of gastric juice under the influence of water may be due to the effect of dilution fully as much as to the increased acidity that accompanies it.

A study of the effect of dilution upon other digestive juices is very urgent and experiments are now planned for this investigation in the case of saliva.

That water begins to pass the pylorus soon after its ingestion has been shown by von Mering 9). To a large dog with duodenal fistula 500 cc. of water were given through the mouth; within 25 minutes 495 cc. were collected through the fistula. In the experiments to be described it was shown that four fifths of the amount of water ingested during a meal, if this amount was large, was voided in the urine within 45-90 minutes thereafter. These facts would seem to give some ground for the contention that the food elements are washed through the stomach and into the intestine before they are thoroughly liquefied and digested.

From the considerations just reviewed the facts regarding the drinking of water with meals seem to be the following: (1) the ingestion of large amounts of water with meals not only does not hinder the normal flow of digestive juices, but acts as an excitant to their flow; (2) the digestive juices are not made less efficient by dilution, on the contrary, enzyme action is more complete the greater the dilution within limits; (3) while the food elements are perhaps washed through the stomach into the intestine more rapidly than is usual, yet over against this is the greater activity and efficiency of digestion. The first two conclusions have been substantiated by experiment. The question as to the completeness of the digestion of the food and the degree to which it is utilized under the conditions of greater dilution and supposedly more rapid movement through the alimentary tract has had but little consideration.

The effect of dilution and increased peristalsis brought on by purgatives was shown by Ury 10) not to increase the amount of soluble food-stuffs or of their products in the feces. His observations were limited to soluble protein and to sugar. Maurel (11) in experiments on guinea-pigs found that water given between meals in amounts beyond what the normal ration would require did not increase the weight of the animals. In similar experiments he found that a reduction every other day to thirty percent of the amount of water usually given caused the animals to lose in weight, due partly to the fact that they ate less. The greater the reduction in water, the greater was the loss in weight, and since the urine volume was not decreased proportionately , a large part of the loss in body weight fell upon the liquid stores of the organism.

Experimental Evidence on the Influence of Water with Meals. The only experimental evidence showing the influence of drinking water with meals comes from an investigation made by Fowler and Hawk 12). Their subject was brought to nitrogen equilibrium on a constant and uniform diet and continuing this diet one liter of water was added to each meal for a time of five days; this was followed by a short final period in which the original conditions held. It appears that the average fecal output per day and the average dry matter per day in the feces were both much less during the water period than during either of the other periods, and that the average amounts during the final period were less than those of the preliminary period. More detailed examination of the feces was confined to the determinations of total and bacterial nitrogen on one stool in each of the three periods. These findings showed that both these

forms of nitrogen were much reduced in amount during the period of copious water ingestion and that after water ceased to be used in unusual amounts these values did not immediately return to the values found for the preliminary period but were still lower than these during the final period. The authors concluded that these findings indicated a more economical utilization of the protein of the food. No data were obtained on fat and carbohydrate utilization. During the water period of five days the subject gained approximately two pounds in weight, and continued to gain for a number of months after the end of the experiment and the return to ordinary mixed diet. How much of this gain in weight was assumed to be due to better assimilation as a result of water-drinking with meals was not stated. It could not be said that the water-drinking had no effect, nor that it had an ill effect.

These conclusions as to the digestibility and availability of the foods during water-drinking were based upon analyses of but three stools, one in each of the three periods. The importance of the conclusions reached seemed to justify more extensive experiments along similar lines, experiments in which each individual stool of the whole investigation should be subjected to careful examination. The data should contain evidence as to the digestion and utilization of carbohydrate, fat and protein and the information regarding their digestibility should be obtained from an examination of the feces alone.

The Feces. The nature and composition of human feces seems generally to be misunderstood. A recent statement is that the feces are chiefly the unabsorbed residues of intestinal excretions.[13)]

A microscopical examination easily shows, however, that this is not true. The composition of feces as given by Schmidt and Strasburger 14) is as follows:

(1) Indigestible material in the food:

(2) Undigested material, which has for some reason escaped the action of the digestive juices;

(3) Residues of the digestive juices;

(4) Bacteria and the products of fermentation and putrefaction;

(5) Products of the epithelial wall, such as decayed cells, leucocytes, &c.

Several findings may be cited in favor of the view that the feces consist chiefly of the unabsorbed residues of intestinal secretions. For example, in the case of dogs, the amount of nitrogen in the feces was not proportional to the amount of meat fed 15). No muscle fibers or protein could be detected in the feces. Voit 16) showed that the feces produced in an isolated loop of the intestine of a dog were of a similar constitution and had the same amount of nitrogen as the feces in the normal intestine through which food was passing. While this is true for the meat-eating dog the conclusions to be drawn from these observations can not be applied to herbivora where only forty-five percent of the energy of the food is of use, nor to man who stands between them. A digestive mechanism such as the dog's whose gastric juice is more than twice as strongly acid as that of man must deal differently with a given food than the human digestive apparatus does with the same food.

Prausnitz in experiments on men 17) showed that the composition of the feces varied with the diet and gave a definition of

normal feces as those resulting from the eating of any food that is completely digested and absorbed. His data also show that the amount of nitrogen in the feces is uninfluenced by the amount in the food, although Schierbeck 18) finds considerable individual variation in this respect. Even if this is so, then, in view of the definition of normal feces, any variation in the nitrogen content of the feces depends upon at least two factors, the amount of the unabsorbed secretions and excretions of the alimentary tract, about which very little is known, and also upon the completeness of the digestion of the food, that is, upon the "normality" of the feces.

A third factor which is, in a way, dependent upon the second, is the amount of bacterial substance in the feces. Strasburger showed 19) that ordinarily about one third of the dry substance of the feces consists of microörganisms, and from one fourth to one half of the fecal nitrogen is bacterial in its origin. From an examination of 266 stools of men on normal mixed diet by MacNeal's modification of Strasburger's method of fractional sedimentation MacNeal, Latzer and Kerr 20) found the average daily bacterial dry substance to be 27.% of the fecal dry substance, and the average daily bacterial nitrogen 46.3% of the total fecal nitrogen; they state that direct quantitative determinations of fecal bacteria furnish evidence of the extent and nature of the bacterial growth in the intestine and that this seems to be a delicate index of intestinal conditions. The pabulum of the intestinal bacteria is the remains of digestive juices and of unabsorbed food-stuffs that reach the lower part of the large intestine. When this food supply is decreased we should expect decreased bacterial growth as a result of lack of nourishment. An increase in unabsorbed food products

and in the residues of digestive juices should result in an increased bacterial growth.

Fats are almost always found in feces, the amount being increased by an increase in the fats in the food. In addition to the food as a source of fat are the digestive juices and the cells of the alimentary epithelia which contain both fats and lipoids. An increased secretion of the juices and a more extensive desquamation of the alimentary epithelia should cause an increase in the fat found in the feces, while if less fat is ingested, or if the other supply is diminished or if the ingested fat is better digested there should be a decrease in the amount of fat that is excreted.

Carbohydrate is present in the feces chiefly in the form of starch. The source of the starch is the ingested food, the vegetable cells of which, as a result of insufficient disintegration, have not become accessible to the action of the digestive juices. The manner of preparing the food has much to do with the extent of this disintegration; the efficiency of the mastication also plays a part, and the activity of the digestive juices and the extent of the churning to which the food is subjected in the intestine also have an influence. All other conditions remaining the same, therefore, the amount of ~~starch~~ carbohydrate found in the feces should furnish some indication as to the digestibility of ~~starch~~ carbohydrate in the organism.

Bearing in mind the above points regarding the significance of nitrogen and its distribution, of fat, and of carbohydrate in the feces, it seemed probable that an examination of the feces with regard to their content of these substances would give an in-

dication as to the efficiency with which protein, fat, and carbohydrate were digested under different conditions.

Description.

General Plan. The general plan of the experiment was to determine in a preliminary period the digestibility of food in men living on a uniform diet. When nitrogen equilibrium was reached, with no change in diet a given volume of water was to be added to that taken normally with each meal and in a final period the conditions of the preliminary period should again obtain.

The subjects of the experiments * were Assistants in Chemistry, well-bodied men weighing respectively 63, 70, and 74 kilograms. The periods began and ended at 7 A.M. and the daily program was as follows. Body weights were taken at 7 A.M. after urinating and defecating. So regular the routine became that in only two or three instances throughout the eight to nine weeks of the experiments defecation did not come at this time. To insure accuracy body weights were always taken without clothing. The morning meal was taken at 7:30, the noon meal at 12 or 12:15, and the evening meal at 5:30 or 5:45. The three meals were identical and consisted of oatmeal crackers, butter, peanut butter, milk, and water. Smaller quantities of water, in amounts as found desirable in the preliminary period, were taken at stated hours during the day. The men went

* Mr. J. E. Egan, Mr. P.E. Howe, and Mr. Frank Wills served as subjects. Their care and faithful attention to the details necessary in such experiments are hereby gratefully acknowledged.

about their duties as usual throughout the day and evening.

The urine was collected in 24-hour samples, the last portion being that passed before weighing in the morning. The urine was analyzed for total nitrogen, ammonia, urea, creatinine, creatine, total and ethereal sulphates and indican.

The analysis of the feces was made on each individual stool. As passed it was weighed and thoroughly mixed until uniform throughout. An aliquot portion of each stool was taken out for the composite sample which was kept in friction-top tin pails previously rinsed out with an alcohol solution of thymol. This method of preservation 21) was entirely satisfactory. The samples for analysis were then weighed out as quickly as possible to prevent loss by evaporation, which is very rapid.

Charcoal was used as a"marker" to facilitate the separation of the feces of different periods; where the uniformity of the diet is not to be interfered with this method is the most satisfactory. One or two gelatin capsules of finely divided charcoal were taken before breakfast on the day beginning a new period; feces showing charcoal were from this breakfast and from the meals following it; the feces free from charcoal were from the preceding day. With but few exceptions the separations thus obtained were distinct and entirely satisfactory.

The length of time between the taking of food and the appearance of the feces therefrom has been variously given. A recent statement is that particles fed to a man are not usually passed in his feces for two or three days. 13) The observations of the present experiments support the opinion as given by Strasburger 22) that normally this period is twenty-four hours. Through-

out these experiments the charcoal given on one morning appeared in the last portions of the feces passed the next morning, in all but two cases, in both of which the separations were from an ordinary mixed diet, that is, at the beginning or at the end of the experiment.

Methods. All analyses were made on fresh feces without previous drying. The samples usually weighed out with the approximate weights are as follows:

(a) Two 2-gram samples for moisture

(b) Two 2-gram samples for total nitrogen where (a) was not used for this purpose

(c) Two 2-gram samples for bacterial nitrogen

(d) Two 2-gram samples for acid-alcohol extract

(e) Two 5-10 gram samples for carbohydrate

(f) Two 5-10 gram samples for fat

Where the stool was too small for all these samples the amount used for fat and carbohydrate was reduced or single determinations were run. Moisture, total nitrogen and bacterial nitrogen were always run in duplicate.

The moisture determination was carried out, during one experiment, in porcelain crucibles, during a second in lead caps. The latter method is much more satisfactory. The samples were first air-dried for two or three days, and then in an oven at 102° C. for two or three days.

During the first experiment these dried samples were used for the total nitrogen determinations, with unsatisfactory results. It was extremely difficult to get the material oxidized without first carefully removing it from the crucibles. In addition to the

possible loss in transferring was the loss in volatile nitrogen compounds during the drying. That there is such a loss the data clearly show; this has been observed before 23) . In the later experiments the determination of total nitrogen was made upon a separate sample of the fresh material with satisfactory results.

All determinations of nitrogen of whatever form were made by the Kjeldahl method which is too well known to require description. Instead of metallic mercury copper sulphate was used as catalyst in the digestion.

Bacterial Nitrogen. The determination of bacterial nitrogen was made by a variation from MacNeal's modified Strasburger method 24) . It was as follows: About two grams of feces are accurately weighed and placed in a 50-cc. centrifuge tube. To the feces in the tube a few drops of 0.2% hydrochloric acid are added and mixed to a smooth paste by means of a glass rod. Further amounts of the acid are added with continued stirring until the material is thoroughly suspended. The tube is then whirled in the centrifuge at high speed for one-half to one minute. By this treatment the suspension is sedimented into more or less definite layers, the uppermost of which is fairly free from the larger particles while it still contains a considerable quantity of the bacteria. The upper three-fourths of the suspension are now drawn off by means of a pipette and transferred to a beaker properly labeled. The sediment remaining in the tube is again rubbed up with the glass rod with the addition of further dilute acid, and again centrifugated for one-half to one minute. The supernatant liquid is pipetted off and added to the first, the same pipette being used for the one determination

throughout. A third portion of the dilute acid is then added to the sediment, again mixed by stirring, and again centrifugated. All the washings are added to the first one, and during the process care is taken to wash the material from the walls and mouth of the centrifuge tube down into it. Finally when the sediment is sufficiently free from bacteria, the various remaining particles are visibly clean, and the supernatant liquid after centrifugation remains almost clear. In the beaker are practically all the bacteria present in the original portion of feces, and in the centrifuge tubes a considerable amount of the other solid matter. The latter is discarded, unless, as in the later experiments this sediment and the others following were all combined in a Kjeldahl flask and run as a separate determination, called residue nitrogen. It represents undigested and insoluble nitrogen. The suspension is now transferred to the centrifuge tubes and centrifugated at high speed for a minute, and the supernatant liquid transferred to a clean beaker by means of a pipette. The tubes are then refilled from the first beaker and thus all the suspension centrifugated a second time. The first beaker is finally carefully washed with the aid of a rubber-tipped glass rod, the second sediment in the centrifuge tubes washed free of bacteria by means of this wash water and by successive portions of dilute acid, and the supernatant liquid after centrifugation added to the contents of the second beaker. The second clean sediment is discarded or added to the first. The bacterial suspension now in the second beaker is again centrifugated in the same way and a third portion of bacteria-free sediment is separated. Frequently a fourth serial centrifugation is performed, always if the third sediment is of appreciable quantity. At all

stages of the separation small portions of the dilute hydrochloric acid are used so that the final suspension shall not be too voluminous. Ordinarily it amounts to 150-300 cc. To the final bacterial suspension an equal volume of alcohol is added and the beaker set aside to concentrate. A water-bath at 50-60° C. is very satisfactory. When concentrated to about 50 cc. the beaker is removed, about 200 cc. of alcohol added, covered, and allowed to stand in the room 24 hours. At the end of this time the bacterial substance is generally settled so that most of the clear supernatant liquid can be directly siphoned off without loss of solid matter. The remainder is then transferred to centrifuge tubes, centrifugated, and the remaining clear liquid pipetted off. The sediment consists of the bodies of the bacteria. Where a determination of bacterial dry substance is desired this sediment is dried by absolute alcohol and ether in succession, transferred to a weighed porcelain crucible and dried at 102° C. to constant weight. Where nothing beyond bacterial nitrogen is desired the sediment after siphoning off the dark brown alcohol is freed from the liquid by centrifugation and nitrogen determined directly.

If, as during the first part of the experiment the acid suspension after removing the last sediment is not treated with alcohol but is directly transferred to Kjeldahl flasks the nitrogen so determined is not only bacterial but includes in addition all nitrogen that is soluble in 0.2% hydrochloric acid or that has become so during the time of manipulation. When the alcohol procedure is carried through and a determination of nitrogen made on the supernatant alcohol this nitrogen represents nitrogen that is not bacterial but which is soluble in 0.2% hydrochloric acid and

not precipitable by alcohol. This comprises therefore all digestion products below the proteose stage and similar nitrogen of the digestive juices and of the pigments, and the alcohol-soluble nitrogen of the bacteria.

Residue nitrogen, as explained was that which came from the well-washed sediments in the centrifugation. It represents insoluble and undigested nitrogen that occurs in the larger particles of the feces.

Extractive Nitrogen. The sample for acid-alcohol extract was rubbed up in a small Erlenmeyer flask with a known volume of 95% ethyl alcohol made 0.2% acid by hydrochloric. This stood for a week and was shaken up at least once each day. Nitrogen was then determined on an aliquot portion (one-half) of the alcohol originally added. This represents likewise such nitrogenous end-products as are below the proteose stage, and the soluble nitrogen of the digestive juices and of the pigments. Almost invariably this amount is less than that obtained by a similar extractive method on the bacterial sample just mentioned. The may be due to the greater fineness of division that is secured in the case of the latter and perhaps also to the solvent action of the 0.2% hydrochloric acid used in making the bacterial suspensions.

Carbohydrate. Carbohydrate was determined by a modification of the method of Strasburger 25). The procedure was as follows. Five to ten grams of feces were weighed out into a 200-cc. Erlenmeyer flask, five to seven grams of bone black were added along with 100 cc. of 2% hydrochloric acid. This mixture was boiled for one and one-half to two hours under a reflux condenser, allowed to

cool, made alkaline with sodium hydroxide to precipitate calcium salts and filtered with suction. Ordinarily this took considerable time. The filtrate was clear and varied in color from a dark straw to entire absence of color. This solution was approximately neutralized and its reducing power was determined in an aliquot portion by the method of Benedict 26). The procedure of Strasburger involves the determination of sugar by the copper thiocyanate method of Volhard-Pflüger, and the time and labor required in this method are considerably greater than for the method used in these experiments. In most cases, also, satisfactory duplicates were obtained. The solutions as prepared for the determination could never be allowed to stand any length of time with neutral or slightly alkaline reaction as the development of molds brought about decompositions and destruction of sugar. When they were left standing they were always acidified.

Fat. Since a measure of the amount of fat in the feces was desired, the method which should yield fat least contaminated with extraneous matter was the one to be used. Of the various methods in use that proposed and developed by Kumagawa and Suto 27) was employed. The modifications as given by Inaba 28) were followed out, and the following was the procedure adopted. About ten grams of moist feces were weighed into a 250-cc. Jena beaker and covered with 45 cc. of 5N NaOH solution. The beaker was covered with a watch-glass and placed on a steam-bath to saponify. The liquid mass was stirred a few times during the first minutes and a homogeneous mixture soon resulted. After several hours, and often much longer, while still hot, the material was poured into a 250-cc.

glass-stoppered separatory funnel and the beaker rinsed several times with warm water. The contents of the funnel was then over-neutralized by adding 54 cc. of 20% HCl in small portions with continued cooling. When well cooled 70 cc. of ether were added to the now acid contents and thoroughly shaken. Separation followed very quickly, a thin layer of insoluble material forming at the junction of the liquids. The water layer was drained off into the original beaker and the ether pipetted off and placed in an Erlenmeyer flask. The precipitate which remained in the funnel was dissolved in a small amount of hot N-NaOH and heated 10-15 minutes on the steam-bath. It was then returned to the separatory funnel and well cooled, and 30-50 cc. of ether added and well shaken. To this alkaline ether solution the acid aqueous solution first drained off was added and in the acid reaction which resulted all the fatty acid appeared quantitatively in the ether portion. The two layers were separated as before and the combined ethers evaporated. The residue was taken up in absolute ether, filtered through asbestos and again evaporated. This residue which contained in addition to the fatty acids lactic acid, pigments, &c., was dried some hours at 50° C., and while still warm 20-30 cc. of petroleum ether were poured upon it with a gentle rinsing movement. A milky cloudiness which was at first evident settled as a tarry mass after about an hour's standing. The petroleum ether was filtered through asbestos, evaporated, and the residue dried at 60° C. to constant weight. The fatty acids so obtained were crystalline and almost colorless. Care to prevent over-heating during the first neutralization and a sufficient drying of the last ether residue before taking up in petroleum ether were essential to obtaining them in pure form.

It is evident that by this method the unsaponifiable substances are determined along with the fatty acid and the authors [27] give a satisfactory procedure by which these may be determined. It was shown by Inaba 28) that the unsaponifiable substances in the feces amount to about ten percent of the total fatty acid determined and that a separation of these substances is of importance if most accurate results are desired. Inasmuch as a uniform diet was fed in these experiments any differences in the fat content of the feces from one period to another are probably subject to no correction on this account.

Experiments on Copious Water-Drinking with Meals.

General Description. The first experiment on subjects H and W may now be considered in detail.

Subject H was a tall well-proportioned man weighing 70.22 kilograms at the beginning of the experiment. He had been on a diet of the comparatively simple variety as offered by lunch counters; as he was not fond of milk and drank neither tea nor coffee water comprised the chief liquid portion of his diet. Subject W was of smaller stature but solidly built. His weight was 63.2 kilograms at the beginning of the experiment. He was accustomed to the variety as offered by a club table of the better grade and usually drank water sparingly. He regularly smoked a cigar after the evening meal and did so throughout the experiment.

Both subjects were put on the same diet. The amounts were altered before nitrogen equilibrium was reached . The quantity and composition as finally given were as follows: Table *.

*The values are from analyses supplemented by data from Bulletin 28, U. S. Dept. Agriculture.

(in grams)	Amount	Nitrogen	Carbohydrate	Fat
Graham Crackers	150.	2.087	108.8	11.7
Peanut Butter	20.	0.882	3.2	9.2
Butter	25.	.020		21.1
Milk	450.(cc)	2.360	25.7	18.0
Water 100 cc.				
Total		5.349	137.7	60.0
	(protein 33.44 g.)			

As stated, this menu was the same for all three meals. In addition 200 cc. of water were taken at 10 A.M., at 3 P.M., and again in the evening or just before retiring, making a total of 900 cc. of water per day during the preliminary period. The water supply of this community is from deep wells and for use in these experiments is was softened by the addition of five liters of saturated lime water to thirty liters of the tap water. After standing several hours to a day the precipitate was filtered off. This water had an agreeable taste; its alkalinity was 70 to phenolphthalein, 180 to methyl orange, and its hardness determined by soap solution was 92 parts per million.

Despite the fact that the diet contained 33.44 grams protein each man states in his diary that his hunger was marked before meals A condition of nitrogen equilibrium was desired for the beginning of the water period. On this diet this was attained approximately at the end of the third day. The exact nitrogen balance may be seen from the following:

Subject H.	Nitrogen in feces	2.153
	urine	14.036
	Nitrogen in excreta	16.189
	in food	16.046
		-.143

Subject W.	Nitrogen in feces	2.385
	urine	14.534
	Nitrogen in Excreta	16.919
	in food	16.046
		- 0.873

On the morning of the fourth day before breakfast charcoal was taken and during the five days following one liter of water was added to the menu of each meal, making 1100 cc. per meal and a total of 3900 cc. per day. On this diet both subjects record a feeling of fulness that often became uncomfortable. It was necessary to urinate frequently especially during the first few hours after the meal; for a short time after eating there was a desire to remain quiet and inactive as is the case after any full meal; within three quarters of an hour or an hour approximately half the water taken at the meal was voided. On one occasion the abdominal pressure became so great as to necessitate defecation; the stool was watery and soft. This will be mentioned again in discussing the data of W. Both subjects record that the feeling of fulness and lassitude became less marked after the second day of the water period. Both felt perfectly well and had a normal appetite. On the fifth day H records that he did not notice the volume of water.

The period of copious water ingestion lasted five days. On the morning of the sixth day charcoal capsules were taken before breakfast and during that and the two following days the diet of the preliminary period was resumed. On the evening of the second day of this period both men record slight pains in the stomach and a feeling of indifference. The experiment ended with the taking of charcoal on the morning of the fourth day of this period.

The data obtained from the analyses of the feces during these three periods are given in tables I and II and will be considered separately.

Data from Subject W, Table I, page 26.

The average amount of feces passed per day during the preliminary period was 177.8 grams, during the water period 119.3 grams, and during the final period 121.1 grams. A similar variation is observed in the fecal dry matter which drops from 46. grams per day in the preliminary to 26.5 grams in the water period and again rises in the final to 31.8 grams. The average daily amount of water in the feces of the preliminary period was 131.8 grams, in the water period 92.8 grams and in the final period 89.3 grams. Notwithstanding the large amount of water passed into the intestine during the water period there was less in the feces during that time than before; the amount of water excreted in the feces in the final period was slightly less than the amount in the water period. The total amount of feces and of dry matter for the final period were only slightly higher than those of the water period and not nearly as high as those of the preliminary, showing that these desirable results are not lost immediately but are more or less permanent. This will be shown more strikingly later.

Digestion and Absorption of Protein. As mentioned before, the determinations of fecal nitrogen in this experiment were unsatisfactory because of the loss of volatile nitrogenous compounds in drying. That nitrogen was lost is very evident from the values of bacterial + soluble nitrogen which are in almost all cases larger than the corresponding total nitrogen. In later experiments,

TABLE I

Period	Number of Stool	Weight	Percent. Dry Matter	Amount Dry Matter	Amount Moisture	Fecal Nitrogen (det)	Fecal Nitrogen (calc)	Bacterial +'soluble Nitrogen
	Weights of Stools					Nitrogen Distrib		
Prel. Per. 3 days	1	147.0	27.33	40.2	106.8	1.738	1.911	1.73
	2	182.5	25.86	47.2	135.3	2.333	2.536	2.30
	3	66.0	27.21	18.0	48.0	.913	.961	.87
	4	138.0	23.67	32.7	105.3	1.649	1.747	1.58
	Total	533.5		138.1	395.4	6.633	7.155	6.50
	Average	177.8	25.9	46.0	131.8	2.211	2.385	2.16
Water 5 days	5	214.0	13.17	28.2	185.8	1.843	(1.387)	1.29
	6	25.2	23.24	5.9	19.3	0.301	0.287	0.26
	7	94.0	27.34	25.7	68.3	1.337	1.433	1.33
	8	102.8	28.85	29.7	73.1	1.499	1.593	1.48
	9	121.5	26.05	31.6	89.9	1.653	1.771	1.65
	10	39.0	29.83	11.6	27.4	.554	.640	.59
	Total	596.5		132.7	463.8	7.187	7.111	6.64
	Average	119.3	22.2	26.5	92.8	1.437	(1.422)	1.32
Final 3 days	11	104.5	25.48	26.6	77.9	1.410	1.459	1.36
	12	134.0	25.83	34.6	99.4	1.805	1.896	1.77
	13.	26.9	31.85	8.6	18.3	0.448	(.431)	.40
	14	98.0	26.10	25.6	72.4	1.329	1.499	1.40
	Total	363.4		95.4	268.0	4.992	5.286	4.94
	Average	121.1	26.3	31.8	89.3	1.664	1.762	1.64

SUBJECT W

.ion

Bacterial Nitrogen	0.2%-HCl-soluble Nitrogen	Acid-alc-soluble Nitrogen	Percentage of Total Fecal Nitrogen found in Bacterial	HCl-Soluble	Acid-alc Soluble	Carbohydrate	Fat
		0.445			23.3	1.955	9.22
		.599			23.6	2.71	10.60
		.193			20.1	1.12	3.85
		.586			33.5	1.78	7.00
		1.823				7.565	30.67
1.279 (calc)	0.889 (calc)	.608			25.5	2.52	10.22
		.280			15.2	2.09	5.80
		.085			28.2	.26	1.31
		.416			29.0	1.51	5.98
		.402			25.2	1.56	6.41
		.458			25.9	1.87	7.01
		.175			27.3	.47	2.64
		2.401				7.76	29.15
.784 (calc)	.545 (calc)	.480			33.4	1.55	5.83
0.817	0.547	.456	56.0	37.5	31.2	1.40	5.56
.970	.802	.571	51.2	42.3	30.1	2.09	7.76
.294	.109	.122	65.6	24.3	27.2	.38	1.84
.866	.535	.373	57.8	35.7	24.9	1.55	6.34
2.947	1.993	1.522				5.42	21.50
.982	.664	.507	55.7	37.7	28.8	1.81	7.17
.972 (calc)	.675 (calc)						

page 37, it was shown that the ratio of total nitrogen to bacterial soluble was fairly constant at 1.10 in the preliminary period and 1.07 in the following periods. Applying this factor to the values under bacterial + soluble nitrogen the values under fecal nitrogen (calc) are obtained. Although these are not values obtained by analysis they are more correct than those actually obtained for the reasons given. Taking either of these values, however, the average daily amount of total nitrogen excreted during the water period is only two thirds of the average daily amount excreted during the preliminary period, and four fifths the average daily amount of the final period. As before, the average daily amount in the final period is only slightly higher than that of the water period, and only three fourths of what it was in the preliminary, showing that the good effect of the water is not immediately lost.

The question as to the kind of fecal nitrogen that was dec eased in amount can not be answered on the basis of analytical data, since the bacterial and acid-soluble nitrogen were not separated during the early part of the experiment. From later experiments in which this separation was made, page 37, a factor was calculated and found to be very uniform for different subjects throughout the various periods. On this basis 59% of the combined bacterial + soluble nitrogen is nitrogen belonging to bacterial substance. That the factor as applied does not fall far short of representing actual conditions may be gathered from the close agreement between the calculated values and those obtained by actual analysis of the stools of the final period, page 26, bacterial nitrogen and 0.2% HCl-soluble nitrogen. Applying this factor to the values for combined bacterial + soluble nitrogen the nitrogen of bacterial

substance in the preliminary period was 1.279 grams per day, in the water period 0.784 gram per day and in the final period 0.972 gram per day. These values indicate that bacterial nitrogen was decreased under the influence of copious water drinking and furthermore, in common with the results found for total fecal nitrogen, this condition was not transitory but more or less permanent. The same statement may be made regarding the 0.2 HCl-soluble nitrogen. The acid-alcohol-soluble nitrogen averaged 25.5 % of the total fecal nitrogen during the preliminary period, 33.4% during the water period, and 28.8% during the final. This may mean that the digestion during the water period resulted in nitrogenous end-products which are more soluble. This increased percentage of acid-alcohol-soluble nitrogen in the feces during the water period does not indicate decreased absorption for the absolute amount of this form of nitrogen in the feces is decreased from 0.608 gram during the preliminary period to 0.480 gram in the water period and rises only slightly above this value, 0.507 gram, during the final period, showing that absorption of the soluble end-products is more complete under the influence of water. More probably, however, this form of nitrogen represents the residual portion of digestive and intestinal juices which are known to increase in amount under the influence of water ingestion, especially the gastric and pancreatic secretions and the bile. If this is so, it is a very important fact, for even though during copious water ingestion, the flow of these secretions is stimulated, and as a result of increased peristalsis the amount of cast-off cellular material in the intestine is increased, the amount of fecal nitrogen instead of being increased, as, indeed, it must be from these sourc-

es is, on the contrary, actually decreased. It follows from this that the digestibility of protein material during a period of copious water-drinking was increased even beyond what the data indicate, since part of the excreted nitrogen is known to come from the larger amounts of digestive juices secreted under the stimulating influence of water.

Attention should be called to the unusual findings on stool 5 whose bacterial + soluble nitrogen forms a much smaller part of the total nitrogen than in any other stool. This will be discussed on page 30.

Digestion and Absorption of Fat. Fat is ordinarily found in the secretion of the pancreas and especially in the bile. The increased flow of these secretions under the influence of water should, therefore, other conditions remaining the same, cause more fat to appear in the feces at such a time. From the data on the excretion of fat it will be seen that such is not the case.

During the preliminary period there was an average daily excretion of 10.22 grams of fat in the feces. During the water period this was reduced to an average of 5.83 grams per day, and in the final period it rose to 7.17 grams per day, an amount only slightly above that of the water period.

From these data it would appear that during the period of copious water-drinking the fats of the food were much more completely digested and absorbed than either before or after this period, and that the good effect of the water-drinking was not temporary but more or less permanent.

Digestion and Absorption of Carbohydrate. The digestive

juices contain no carbohydrates and probably no reducing substances; any carbohydrate in the feces has its origin in the food ingested. By reference to the table giving the data on carbohydrate excretion in the feces of subject W it is seen that the average daily excretion during the preliminary period was 2.52 grams, during the water period 1.55 gram , and during the final period 1.81 gram . Here it appears again that the effect of the large amount of water was to secure a better digestion and more complete utilization of ingested carbohydrate, and the influence of the water extended beyond the time in which it was used.

The amount of carbohydrate in stool 5, the first of the water period is 2.09 grams, the largest amount during any day of the period. This is the more striking since the entire stool contained only 28.2 grams solid matter, of which 5.8 grams were fat. The total nitrogen was also above the average, and the bacterial and extractive or acid-alcohol-soluble portions were unusually low. All of these facts indicate incomplete digestion of the food. This stool was mentioned before as being the only one that gave any enidence of having been forced out of the intestine by the pressure of the ingested water. It was passed immediately after breakfast on the morning of the second day of water. Before breakfast stool 4 had been passed; this contained none of the charcoal that had been taken before breakfast on the morning of the day before, the first day of the water. Charcoal was found in 5. W records a feeling of pressure on the first day of water as well as on the second, but on the second it seemed to increase. Stool 5 gives evidence from its high content of water and of food-stuffs that it was forced out before the time necessary for satisfactory digestion and absorption.

Notwithstanding that this, the first stool of the water period contained undigested protein, fat and carbohydrate, nevertheless an examination of the data shows that the average daily output of those substances was markedly lowered under the influence of water ingestion.

A slight gain in weight accompanied this experiment. On the morning of the first day of water W's weight was 63.46 kilograms: at the end of this period it was 64.16 kilograms. This gain of 700 grams might be attributed to attained water, except for the fact that it was not lost subsequently. After the lapse of three months, during which time the subject was on an ordinary mixed diet his weight was identically the same as at the end of the water period of this experiment. While great significance can not be attached to so small a change in weight, even granted that it is not due to water, it must nevertheless be borne in mind that the diet throughout the experiment was absolutely uniform with the exception of the water ingestion.

Data from Subject H. The facts regarding the digestibility of protein, fat and carbohydrate as influenced by copious water ingestion in the case of subject W were also observed in Subject H. The data obtained from the analysis of the feces are given in Table II, page 32.

The average daily amount of feces passed during the water period was less than that in either preliminary or final periods. The average amount in the period after the water is less than that in the period before the water. The average daily dry matter suffered a similar drop during the water period. The amount of

Table II

	Weights of	Stools				Nitrogen	Distri
Number of Stool	Weight	Percent. Dry Matter	Amount Dry Matter	Amount Moisture	Fecal Nitrogen (det)	Fecal Nitrogen (calc)	Bacterial + soluble Nitrogen
Prel. Per. 3 days 1	42.5	29.42	12.5	30.0	0.676	0.743	0.675
2	87.0	26.54	23.1	63.9	1.214	1.427	1.297
3	158.0	26.57	42.0	116.0	2.206	2.654	2.413
4	104.0	26.21	27.3	76.7	1.443	1.635	1.486
Total	391.5		104.9	286.6	5.499	6.459	5.871
Average	130.5	26.8	35.0	95.5	1.833	2.153	1.957
Water 5 days 5	54.0	17.71	9.6	44.4	.514	.537	..502
6	81.7	27.95	22.8	58.9	1.113	1.249	1.167
7	43.0	31.68	13.6	29.4	.695	.761	.711
8	269.5	24.33	65.6	203.9	3.325	3.602	3.366
9	141.0	22.00	31.0	110.0	1.563	1.788	1.671
Total	589.2		142.6	446.6	7.210	7.937	7.417
Average	117.8	24.2	28.5	89.3	1.442	1.587	1.483
Final 3 days 10	101.0	23.90	24.1	76.9	1.229	1.415	1.322
11	25.5	33.40	8.5	17.0	.442	.477	.446
12	112.0	27.90	31.3	80.7	1.510	1.763	1.648
13	141.5	25.92	36.7	104.8	1.726	2.028	1.895
Total	380.0		100.6	279.4	4.907	5.683	5.311
Average	126.7	26.2	33.5	93.1	1.636	1.894	1.770

Subject H

Bacterial Nitrogen	0.2% HCl soluble Nitrogen	Acid-alc-soluble Nitrogen	Percentage of Total Fecal Nitrogen found in: Bacterial	HCl-soluble	Acid-alc-soluble	Carbohydrate	Fat	Number of Stool
		0.208			28.0	0.57	3.23	1
		.342			24.0	1.20	5.16	2
		.756			28.5	2.37	9.73	3
		.653			39.9	1.80	7.00	4
		1.959				5.94	25.12	Tota
1.155 (calc)	0.802 (calc)	.653			30.3	1.98	8.37	Aver
		.280			52.1	.66	2.16	5
		.447			35.8	1.45	5.65	6
		.238			31.3	.82	3.58	7
		1.134			31.5	3.89	16.59	8
		.655			36.6	1.87	7.80	9
		2.754				8.69	35.78	Total
.875 (calc)	.608 (calc)	.551			34.7	1.74	7.16	Avera
.819	.503	.503	57.9	35.6	35.6	1.06	6.06	10
.302	.144	.119	63.3	30.2	24.9	.37	2.14	11
1.082	.566	.563	61.4	32.1	31.9	1.71	8.79	12
1.180	.715	.671	58.2	35.3	33.1	1.92	10.68	13
3.383	1.928	1.856				5.06	27.67	Total
1.128	.643	.619	59.6	34.0	33.7	1.69	9.22	Aver
1.044 (calc)	.726 (calc)							

water in the feces during the water period was also less than during the preliminary or final periods showing that even with the large amounts of water sent into the intestine the amount absorbed was actually more than the excess administered.

Again, taking the values for total fecal nitrogen either those determined directly on dry feces or those calculated from the bacterial + soluble nitrogen, it is seen that the average daily excretion of nitrogen was much less during the water period than during either of the others, and the average daily amount after the water was less than that before it.

As with subject W the kinds of fecal nitrogen that suffered a decrease can not be stated on the basis of analyses. The results on applying to the value for bacterial soluble nitrogen the factor 0.59 which was obtained from later experiments as has been explained show that the average bacterial nitrogen per day was decreased from 1.155 in the preliminary to 0.875 in the water period, rising to 1.044 in the final. The average daily output as determined for the final period is 1.128 showing that the factor used is accurate. The same proportionate differences are to be noticed in the values for soluble nitrogen. It is evident that both bacterial and soluble nitrogen in the feces underwent a marked decrease during the period of copious water-drinking with the meals.

The percentage acid-alcohol-soluble nitrogen rose from an average of 30.3 in the preliminary to 34.7 during the water period and fell to 32.7 in the final, while the actual amount fell from 0.653 in the preliminary to 0.551 in the water and rose to 0.619 grams per day in the final period. The actual amount of this form of nitrogen was considerably decreased under the influence of

water-drinking. The suggestion may be made again that the increased percentage output was probably due to the increased volume of digestive juices the secretion of which was stimulated by the ingestion of water.

Fat. The data regarding the excretion of fat show that the average per day during the preliminary period, 8.37 grams, fell to 7.16 grams per day during the water period, and rose to 9.22 grams per day in the final period. The digestion and absorption of fat was clearly more complete during the water period than during the preliminary period. Here, for the first time, the daily average amount of an ingested food-stuff in the feces is higher in the final period after the water than in the preliminary period.

Carbohydrate. The data from the carbohydrate determinations are not as striking as those from subject W but the variations are in the same direction. The average daily excretion during the preliminary period, 1.98 grams, fell to 1.74 grams during the water period, and was still less, 1.69 grams per day in the final period.

Aside from a feeling of fulness during the first days of water-drinking H records a general well-being. The large volume of water became less noticable as the days of the experiment went by, and on the last day, the fifth of water-drinking, it was not noticed at all. This subject also records a slight gain in weight, 70.29 kilograms on the morning of the first day of water and 70.88 on the morning of the first day after the water. This gain of 600 grams was not lost for at least three months thereafter.

Inferences. The findings obtained in this investigation

as to the digestibility of food during copious water-drinking with meals corroborate those of Fowler and Hawk 12) in that during the period when large amounts of water were taken with the meals the total amounts of feces, of fecal dry matter and of fecal water, were less than without the unusual amounts of water, and that the values for fecal, bacterial and soluble nitrogen were also all reduced. A slightly less pronounced gain in weight was shown. It was further shown in this experiment that better digestibility extended also to fat and carbohydrate food and that this distinctly beneficial effect of water was not temporary but was prolonged beyond the time during which water was being taken. Absolutely no harmful effects could be demonstrated.

Experiments on Moderate Water-Drinking with Meals.

Having found that many distinc ly beneficial and no harmful results were attained by the ingestion of large amounts (one liter) of water with meals, it seemed very desirable to learn whether or not these beneficial results could be secured by the use of a smaller amount of water, 500 cc., an amount that might be called moderate, and administered for a longer period, ten days instead of five.

Description, Methods, &c. The plan of the experiment was exactly the same as that of the one already described. Two subjects were brought to nitrogen equilibrium on a uniform diet and a given small water ingestion. During a period of ten days in which the same diet was continued, 500 cc. of water in addition to the usual amount were taken with each meal. In a final period the conditions

of the preliminary period were again in force. The daily routine was the same as in the preceding experiment and the diet consisted of the same substances as before.

Charcoal was used to separate the feces of the different periods and the analyses were made on each individual stool in a fresh condition. As stated before, the moisture determinations in this experiment were made in lead caps and were eminently satisfactory. Total nitrogen determinations were made on the fresh moist material and the loss in volatile nitrogen compounds due to drying was thus avoided. The determination of residue nitrogen as previously described was made throughout this experiment.

A more accurate and trustworthy separation of the bacterial + soluble nitrogen was made by an efficient centrifugation of the final alcohol suspension from which as much as possible of the clear liquid had been pipetted off. The nitrogen of the precipitated material could more truly be called bacterial nitrogen, that of the liquid acid-soluble nitrogen.

Throughout most of this experiment the values for bacterial nitrogen and for nitrogen in the alcohol extract of bacteria, that is the acid-soluble nitrogen, were determined along with a determination of the bacterial soluble nitrogen, that is, the same suspension without alcohol treatment. The agreement between the last-named and the sum of the first two is very satisfactory; in almost all cases they would pass as duplicates. The fact that the alcohol used was not previously freed from possible traces of nitrogen may account for the uniformly higher values given by the sum of the separate alcohol-soluble and bacterial determinations.

It was found from these data that the bacterial nitrogen was

59% of the combined bacterial soluble nitrogen and this ratio was used in the preceding experiment as mentioned on page 27 . The ratio of total fecal nitrogen to bacterial + soluble nitrogen used in the first experiment, page 27, was obtained from the values for these forms in this experiment. In both tables III and IV this was approximately 1.10 in the earlier periods and 1.07 in the later periods.

Acid-alcohol-soluble nitrogen was determined as before, so also fat and carbohydrate.

As already mentioned, W served as subject on this experiment. During the time that had passed since the first experiment he had been at the same table as before had had much the same kind of food and in general the same dietary habits with the exception that he had formed the habit of taking more water with his meals than before the first experiment. His weight at the beginning of this one was 64.18 kilograms, almost exactly the same as at the end of the first experiment.

Subject E was tall and of the average build , and weighed 73.6 kilograms. His habits of eating were irregular. During the previous year he had for a time lived on one substantial lunch-counter meal a day, later on two, and during the months preceding the experiment, on three at a regular table. He was accustomed, ordinarily, to taking considerable amounts of water with his meals. During the preceding year while he was serving as subject on another metabolism experiment and was on a uniform diet a pronounced intestinal fermentation made itself evident by a stool of high moisture content. Although he was subject to a condition of this kind even on an

ordinary mixed diet he happened not to make mention of this and was therefore accepted for the present metabolism study. The condition was one peculiar to the organism and was not dependent upon such external conditions as could easily be determined and controlled.

The diet of subject W was slightly reduced from what it had been in the preceding experiment. The amounts and composition were as follows:

(in grams)	Amount	Nitrogen	Carbohydrate	Fat
Graham Crackers	125.	1.776	90.6	10.8
Peanut Butter	20.	.868	3.2	9.2
Butter	25.	.015		21.1
Milk	400 cc.	1.917	22.8	16.0
Water 100 cc.				
Total		4.577	116.6	57.1
	Protein	28.61		

The diet of subject E consisted of

Graham Crackers	150.	2.120	108.8	12.9
Peanut Butter	20.	.868	3.2	9.2
Butter	25.	.015		21.1
Milk	400 cc.	1.917	22.8	16.0
Water 100 cc.				
Total		4.920	134.8	59.2
	Protein	30.75		

The three meals of the day were identical. 200 cc. of water were taken at 10 A.M., at 3 and at 8:30 P.M., making a total water ingestion of 900 cc. per day during the preliminary period. The water used was softened as described above. The progress of the experiment and the data of each man will now be taken up separately.

Data from Subject W .

On the diet as given some little difficulty was experienced in obtaining nitrogen equilibrium in the preliminary period. Charcoal was taken on the morning of the eighth day but for the sake of keeping uniformity in the feces data it seemed best not to change the diet. Six days more passed and on the morning of the fourteenth day charcoal was again taken and water added to the regular diet. The data on the nitrogen equilibrium are as follows:

Nitrogen in feces	1.360
urine	12.361
Nitrogen in excreta	13.721
in food	13.731
	+ 0.010

The separation of the preliminary period into two parts proved to be a very fortunate happening in view of what the feces data show . Table III, page 40.

It will be remembered that during the time that intervened between the two experiments, subject W , while on an ordinary mixed diet continued the habit of taking considerable water with the meals. As is evident from the diet of the preliminary period the amount of water allowed was small and was, in fact, much less than he was accustomed to use. While this restricted amount of water did not immediately make itself felt in the first few days of the experiment, it did begin to show in the latter part of the preliminary period by a less complete digestion and absorption of the food. This is evident in an increase in the average daily fecal output during the second part of the preliminary period. The average amount of feces passed per day during the first part of this

Table III

Number of Stool		Weights of Stools: Weight	Percent. Dry Matter	Amount Dry Matter	Amount Moisture	Nitrogen Distribution: Total Fecal Nitrogen	Bacterial + soluble Nitrogen	Bacterial + soluble separate	Bacterial Nitrogen
Prel. Per. I 7 days	1	155.5	25.94	40.3	115.2	2.152	1.906		
	2	39.2	31.57	12.4	26.8	.618	.556		
	3	63.7	27.78	17.7	46.0	.878	.789		
	4	72.0	28.92	20.8	51.2	1.070	.990		
	5	201.8	27.04	54.6	147.2	3.075	2.760		
	6	90.9	23.50	21.4	69.5	1.131	.993		
	Total	623.1		167.2	455.9	8.924	7.994		
	Average	89.0	26.85	23.9	65.1	1.275	1.142		
Prel. Per. II 6 days	7	62.8	25.61	16.1	46.7	.845	.790	0.816	0.483
	8	98.8	26.72	26.4	72.4	1.265	1.208	1.199	.693
	9	109.8	27.50	30.2	79.6	1.491	1.324	1.388	.791
	10	185.8	24.10	44.8	141.0	2.213	2.008	2.057	1.107
	11	41.8	31.23	13.1	28.7	.673	.574	.549	.287
	12	104.9	24.28	25.5	79.4	1.254	1.136	1.084	.590
	13	24.0	32.87	7.9	16.1	.418	.355	.358	.194
	Total	627.9		164.0	463.9	8.157	7.396	7.450	4.144
	Average	104.6	26.10	27.3	77.3	1.360	1.233	1.242	.691
Water Period 10 days	14	31.6	23.90	7.6	24.0	.388	.352	.368	.200
	15	147.5	27.52	40.6	106.9	2.044	1.959	1.867	.984
	16	75.4	26.20	19.8	55.6	1.029	.990	.986	.563
	17	144.8	27.45	39.8	105.0	2.044	1.929	1.929	1.087
	18	63.9	26.84	17.2	46.7	.899	.790	.831	.440
	19	115.5	27.10	31.3	84.2	1.616	1.510	1.495	.873
	20	26.0	27.49	7.2	18.8	.377	.337	.345	.198
	21	169.0	26.52	44.8	124.2	2.355	2.249	2.254	1.298
	22	127.0	24.35	30.9	96.1	1.672	1.533	1,549	.881
	23	152.7	23.26	35.5	117.2	1.918	1.751	1.813	.996
	Total	1053.4		274.7	778.7	14.343	13.400	13.437	7.520
	Average	105.3	26.12	27.5	77.8	1.434	1.340	1.344	.752
Final Period 5 days	24	60.0	24.67	14.8	45.2	.775	.730	.724	.416
	25	119.6	23.38	28.0	91.6	1.497	1.383	1.391	.823
	26	51.1	27.50	14.1	37.0	.758	.694	(.694)	.461
	27	142.7	25.05	35.8	106.9	1.845	1.738	1.955	1.160
	28	81.4	27.96	22.8	58.6	1.238	1.153	1.201	.758
	29	53.4	30.61	16.4	37.0	.875	.830	.872	.539
	Total	508.2		131.9	376.3	6.988	6.528	6.837	4.157
	Average	101.6	25.90	26.3	75.3	1.398	1.306	1.368	.832

Subject W

Percentage of Total Fecal Nitrogen found in

0.2% HCl soluble Nitrogen	Acid-alc-soluble Nitrogen	Residue Nitrogen	Bacterial + soluble	Bacterial	0.2% HCl-soluble	Acid-alc-soluble	Residue	Carbohydrate	Fat
	0.460	0.323	88.6			21.4	15.0	3.16	12.30
	.143	.076	90.0			23.2	12.2	1.14	3.19
	.213	.100	89.9			24.3	11.4	1.92	4.23
	.234	.109	92.5			21.9	10.2	1.89	4.71
	.684	.269	89.8			22.3	8.8	5.22	12.20
	.255	.159	87.8			22.6	14.0	1.74	5.06
	1.990	1.035						15.07	41.69
	.284	.148	89.6			22.3	11.6	2.15	5.96
0.336	.190	.071	93.6	57.2	39.5	22.5	8.4	1.52	4.20
.506	.277	.127	95.5	54.8	40.0	21.9	10.0	2.08	7.47
.597	.362	.132	88.8	53.0	40.1	24.3	8.9	3.05	8.07
.949	.544	.271	90.7	50.0	42.9	24.6	12.3	3.58	10.52
.262	.161	.109	85.3	42.6	39.0	23.9	16.1	1.03	3.21
.494	.298	.169	90.6	47.0	39.4	23.8	13.5	2.15	5.97
.163	.088	.044	85.1	46.6	39.1	21.8	10.5	.45	1.90
3.306	1.920	.922						13.86	41.34
.551	.320	.154	90.7	50.8	40.5	23.5	11.3	2.31	6.89
.168	.103	.028	90.6	51.4	43.3	26.5	7.2	.25	1.64
.884	.530	.207	95.8	48.1	43.2	25.9	10.1	2.25	10.18
.424	.249	.083	96.3	54.7	41.2	24.2	8.0	1.20	4.70
.841	.521	lost	94.4	53.2	41.2	25.5	--	2.60	9.70
.390	.215	.123	87.8	49.0	43.4	24.0	14.0	1.37	3.89
.621	.404	.163	93.4	54.0	38.4	25.0	10.1	2.51	7.54
.147	.087	.042	89.3	52.5	39.1	23.0	11.1	.56	1.74
.957	.583	.195	95.5	55.1	40.6	24.8	8.3	4.60	11.59
.668	.409	.172	91.7	52.7	40.0	24.5	10.3	2.93	7.85
.817	.498	.211	91.3	51.9	42.6	26.0	11.0	3.54	8.72
5.917	3.599	1.224						21.81	67.75
.592	.360	.136	93.4	52.4	41.3	25.1	9.5	2.18	6.78
.307	.184	.062	94.2	53.7	39.6	23.8	8.0	1.34	3.54
.568	.355	.099	92.4	55.0	38.0	23.7	6.6	2.41	6.58
.233	.195	.079	91.6	60.9	30.8	25.7	10.5	1.10	3.36
.795	.488	.163	94.2	62.9	43.1	26.5	8.8	2.27	8.56
.444	.292	.100	93.1	61.2	35.8	23.6	8.1	1.82	5.54
.333	.207	.070	94.8	61.6	38.1	23.6	8.0	1.39	4.08
2.680	1.721	.573						10.33	31.66
.536	.344	.115	93.4	59.5	38.4	24.6	8.2	2.07	6.33

period was 89. grams, as against 104.6 grams in the second. The average daily dry matter content during the first part of this period was 23.9 grams as against 27.3 grams during the second part. The difference is small but not inconsiderable. As is evident from the data this increase in fecal material comes by an increase in all forms of nitrogen determined. Total fecal nitrogen rises from 1.275 to 1.360, bacterial + soluble from 1.142 to 1.233, acid-alcohol soluble from 0.284 to 0.320, and residue nitrogen from 0.148 to 0.154 . Fat and carbohydrate also show an increase, fat from 5.96 to 6.89 and carbohydrate from 2.15 to 2.31. Since the charcoal separation of this preliminary period into two portions was clear and definite this increase in nitrogen, carbohydrate and fat in the feces during the latter part can mean nothing but a less efficient digestion and utilization of the food due to insufficient amounts of water. That this evidence did not appear until some days after the amount of water had been reduced indicates, as in the first experiment, that the beneficial effect which water has upon the digestion and absorption of food-stuffs does not cease with the with-drawal of water, but is more or less permanent beyond the time during which water is taken with the meals. The evidence given by this finding was unsought for and is of great importance.

Attention should also be called to the comparison of the feces data of this preliminary period with those of the preliminary period of the first experiment, Table I, page 26. The average daily amount of feces in the preliminary period of the first experiment was 177.8 grams, as against 89.0 in the second; dry matter 46.0 in the first as against 23.9 in the second; fecal nitrogen 2.385 as against 1.275; bacterial + soluble nitrogen 2.168

as against 1.142; acid-alcohol-soluble 0.608 as against 0.284; fat 10.22 as against 5.96 and carbohydrate 2.52 as against 2.15. The average percentage of utilization of protein in the first experiment was 86.3 % as against 90.7% in the second, of carbohydrate 99.4% in both experiments and of fat 94.3% in the first as against 96.5 % in the second.

These data showing so pronounced an improvement in the digestion and utilization of food are on an individual living on the same kind of diet separated by a period of three months in which water-drinking with ordinary meals was practiced. From these results only one conclusion can be drawn as to the effect of water-drinking with meals.

With the fourteenth day 500 cc. of water were added to the diet of each meal and this was continued for ten days. A five-day period followed in which the original conditions prevailed.

Protein. By referring to Table III it will be seen at once that the nitrogen of the various periods present no striking differences. The values for the daily average feces and dry matter, and for total, bacterial and other forms of nitrogen show fluctuations which are too small to admit of conclusions. The largest proportionate variation is seen in the residue nitrogen. This, as was explained, was obtained from the solid material that was sedimented in the procedure for bacterial nitrogen. Its percentage of the total nitrogen, 11.3 in the preliminary period, fell to 9.5 in the water period, and still lower, to 8.2 in the final period. If these small differences are significant they point to a condition of better digestion although from the nitrogen data this is not

accompanied by better absorption.

Carbohydrate. An examination of the data upon carbohydrate excretion reveals differences that are small but nevertheless in the same direction as noted in the experiment on copious water-drinking. The daily average excretion in the preliminary period, 2.31 grams, fell to 2.18 grams in the water period, and still lower, to 2.07 grams, in the final period.

Fat. The average daily excretion of fat in the preliminary period, 6.89 grams, showed but little change in the water period, 6.78 grams, but was slightly decreased in the final period. Just why this decrease should have come in the final period rather than during the water period is not clear. There may be at times a lag in the appearance of the results of water-drinking, just as it has been shown that its effects are more or less permanent. In this case the moderate amount of water may have had a stimulatory effect that was not evident during the water period but made itself felt during the period following. The question of individuality probably enters in also.

From a study of the data on Subject W during this experiment it may be concluded that the effect of moderate water-drinking with meals upon digestion is in the same direction as that of copious water-drinking but somewhat less marked. The changes observed in protein digestion are too small to be significant, those on carbohydrate are more evident, and those on fats are still more pronounced. Where significant data could be obtained the effect of the ingestion of a moderate amount of water with the meals, far from

being harmful was seen in subject W to be beneficial to the digestion and utilization of the food.

Data from Subject E. On the diet given the nitrogen balance of Subject E at the end of the sixth day was as follows:

Nitrogen in Feces	1.926
Urine	13.320
Nitrogen in Excreta	15.246
in Food	14.761
	- 0.485

On the morning of the eighth day charcoal was taken and thereafter, during ten days, 500 cc. of water were added to each meal. During a four-day final period the original conditions obtained.

Protein. An examination of the data in Table IV, page 45, reveals no striking differences in the nitrogen values from one period to another. The variations in average daily weight of feces and dry matter and in average daily amounts of nitrogen in its various forms are, as in the case of W, too small to be significant, with the possible exception of the values for the residue nitrogen. The percentage of the total nitrogen found in this form during the preliminary period, 11.1, fell to 10.2 in the water period and rose to 10.9 in the final. Similar variations, and in the same direction were noted under W. Attention may be called again to the satisfactory agreement of the values for bacterial + soluble nitrogen with the values of the sum of these two determined separately, which thus furnishes a valuable check on the determinations.

Weights Of Stools — Nitrogen Distribu

	Number of Stool	Weight	Percent Dry Matter	Amount Dry Matter	Amount Moisture	Total Fecal Nitrogen	Bacterial + soluble Nitrogen	Bacterial + soluble separate	Bacterial Nitrogen
Prel Period 7 days	1	88.4	20.81	18.4	70.0	1.141	0.945		
	2	30.2	26.56	8.0	22.2	.461	.457		
	3	179.2	23.01	41.2	138.0	2.420	2.251		
	4	193.9	24.67	47.8	146.1	2.867	2.591		
	5	76.9	26.17	20.1	56.8	1.219	1.104		
	6	207.7	22.78	47.3	160.4	2.846	2.587		
	7	124.6	22.30	27.8	96.8	1.744	1.581		
	8	44.0	29.42	12.9	31.1	.784	.731		
	Total	944.9		223.7	721.2	13.481	12.247		
	Average	135.0	23.70	32.0	103.0	1.926	1.750		
Water Period 10 days	9	76.5	22.87	17.5	59.0	1.048	.923	0.921	0.536
	10	140.9	20.88	29.4	111.5	1.837	1.713	1.723	1.085
	11	63.8	29.16	18.6	45.2	1.158	1.087	1.091	.685
	12	169.0	24.30	41.1	127.9	2.577	2.398	2.405	1.372
	13	247.5	19.19	47.5	200.0	3.133	2.678	2.700	1.443
	14	135.3	22.96	31.1	104.2	1.896	1.706	1.767	1.019
	15	192.4	19.58	37.7	154.7	2.389	2.059	2.165	1.083
	16	79.2	24.58	19.5	59.7	1.144	1.015	1.032	.523
	17	55.9	27.17	15.2	40.7	.811	.806	.787	.425
	18	173.5	24.91	43.2	130.3	2.567	2.377	2.353	1.343
	19	51.5	27.98	14.4	37.1	.818	.790	.808	.445
	Total	1385.5		315.2	1070.3	19.378	17.551	17.752	9.958
	Average	138.6	22.73	31.5	107.1	1.938	1.755	1.775	.996
Final 4 days		67.3	23.60	15.9	51.4	.943	.829	.828	.425
	21	117.8	26.08	30.7	87.1	1.855	1.675	1.703	1.015
	22	147.7	23.19	34.3	113.4	2.045	1.861	1.864	1.068
	23	145.9	26.49	38.7	106.2	2.251	2.086	2.158	1.243
	24	31.2	31.55	9.8	21.4	.538	.493	.502	.195
	Total	509.9		129.4	380.5	7.631	6.944	7.055	3.946
	Average	127.5	25.34	32.3	95.2	1.908	1.736	1.764	.937

Subject E

Percentage of total Fecal Nitrogen Found in

0.2 % HCl-soluble Nitrogen	Acid-alc-soluble Nitrogen	Residue Nitrogen	Bacterial + soluble	Bacterial	0.2 % HCl-soluble	Acid-alc soluble	Residue	Carbohydrate	Fat
	0.236	0.159	82.8			20.7	13.9	2.48	3.79
	.106	.056	99.1			23.0	12.1	1.18	1.51
	.530	.235	93.0			21.9	9.7	4.98	8.96
	.679	.312	90.4			23.7	10.9	7.21	11.63
	.262	.130	90.6			21.5	10.7	2.37	3.92
	.654	.328	90.9			23.0	11.5	5.31	8.66
	.366	.206	90.6			21.0	11.8	3.49	5.20
	.176	.072	93.3			22.5	9.2	1.38	2.63
	3.010	1.497						28.40	46.30
	.430	.214	9[illegible].9			22.3	11.1	4.06	6.61
0.386	.233	.138	88.0	51.1	36.8	22.2	13.2	2.48	3.33
.638	.380	.194	93.2	59.1	34.7	20.7	10.6	4.47	5.85
.406	.241	.072	93.9	59.2	35.1	20.8	6.3	1.55	3.96
1.033	.571	.214	93.0	53.3	40.1	22.2	8.3	4.04	8.20
1.257	.713	.376	85.5	46.1	40.1	22.8	12.0	4.80	9.78
.748	.419	.192	90.0	53.8	39.5	22.1	10.1	3.33	6.50
1.081	.589	.242	86.2	45.4	45.3	24.7	10.1	4.18	7.07
.509	.264	.140	88.7	45.7	44.5	23.1	12.3	1.33	3.63
.362	.207	.102	99.4	52.4	44.7	25.5	12.6	1.48	2.90
1.010	.630	.232	92.6	52.3	39.3	24.5	9.0	3.68	9.59
.363	.205	.075	96.5	54.4	44.4	25.1	9.2	1.17	3.10
7.794	4.452	1.978						32.51	63.91
.779	.445	.198	90.6	51.4	40.2	23.0	10.2	3.25	6.39
.403	.213	.146	87.9	45.1	42.7	22.5	15.4	1.42	2.79
.688	.429	.196	90.3	54.7	37.1	23.1	10.6	2.76	5.60
.796	.446	.199	91.0	52.2	38.9	21.8	9.8	3.46	7.75
.915	.556	.230	92.7	55.2	40.6	24.7	10.2	4.53	7.88
.308	.126	.059	91.7	36.2	57.2	23.4	10.9	.81	2.77
3.109	1.769	.830						12.98	26.79
.777	.442	.207	91.0	51.7	40.7	23.2	10.9	3.25	6.70

Carbohydrate. The average daily excretion of carbohydrate dropped from 4.06 grams to 3.25 grams during the water period, and stayed at the same value in the final. This is a small difference to be significant but on a uniform diet the evidence is creditable; it points to the same conclusion for moderate water-drinking that has been reached up to this time for copious water-drinking.

Fat. Although the differences are slight the data on the fat excretion also show a drop in these values for the water period. The output of fat fell from 6.61 grams per day to 6.39 grams under the influence of moderate water-drinking. and again rose to 6.70 in the final period.

Inferences. Again, and particularly in the data upon fat and carbohydrate excretion it appears that the effect of drinking water in moderate amounts with meals is in the same direction as when large amounts are used, although the differences observed are of a smaller order of magnitude, and as with the copious amounts, absolutely no harmful effects were observed.

With moderate amounts of water the inconvenience of disposing of an unusual quantity of liquid after the meal was removed and the lethargic effects of a full meal, such as were noted under the experiment on copious water-drinking were also avoided.

The results just given were obtained on subjects one of whom, (W) had lately become accustomed to drinking with meals, the other of whom (E) habitually took fairly large amounts of water with his meals. In each case, the organism though accustomed to the presence

of water in the alimentary tract during digestion responded to an increase in its amount by a better utilization of the food materials. The results obtained therefore probably represent the minimum rather than the maximum effect that may be obtained by moderate water-drinking with meals, and are such as might safely be expected in any individual but especially in one not accustomed to drinking water under these conditions.

The Effect of Copious Water-Drinking with Meals upon an Habitual Water-Drinker.

Thus far the effect of copious water-drinking with meals had been observed on subjects that were accustomed to drinking but little water with meals (H and E , Experiment I); also the effect of moderate water-drinking was studied in subjects who were accustomed to drinking with their meals (W and E Experiment II). There remained to study the effect of copious water-drinking upon a subject accustomed to drinking considerable amounts of water with meals. For this purpose E seemed very well fitted since he had frequently made it his boast during the experiment on moderate water-drinking that he was not drinking more water with his meals during the water period than was his custom. It seemed advisable therefore to try upon E the effect of such amounts of water as would be copious for his digestive mechanism.

Description. Continuing with the same diet as in the final period of the last experiment, a period of six days was made the preliminary for this experiment; during this time the effect of the water, if there was such, might wear off. In the five days

following this one and one third liters of water was taken with each meal. This is a larger amount of water than was used in the first experiment on copious water-drinking where only 1100cc. were taken with each meal. A final period of three days closed the experiment.

The nitrogen balance at the beginning of the experiment was as follows:

Nitrogen in	Feces	1.957
	Urine	12.775
Nitrogen in	Excreta	14.732
	in Food	14.761
		+ 0.029

On the very first day of this large water ingestion subject E records that he had no trouble in drinking all of the water nor was any discomfort experienced.

Data. An examination of the data in Table V, page 49, shows that the average amount of feces excreted per day was 133.4 grams during the preliminary period, 152.5 grams during the water period, and 157.3 grams in the final period. This marked increase during the water and final periods is not evident from the values for dry matter. During the preliminary period this averaged 32.3 grams per day, during the water period 32.2 grams per day, and during the final 33.6 grams per day, values which are strikingly uniform.

The apparent increase in the average daily amount of feces was thus due to water only, and it would seem that the absorption limit of water in the intestine had been reached. While no difficulty was experienced in drinking the large volume of water, the

Table V

	Number of Stool	Weight	Percent. Dry Matter	Amount Dry Matter	Amount Moisture	Total Fecal Nitrogen	Bacterial + soluble Nitrogen	Bacterial + soluble separate	Bacterial Nitrogen
		Weights of Stools				Nitrogen Distribution			
Prel. Period 6 days	1	35.2	28.88	10.2	25.0	0.572	0.517	0.521	0.307
	2	66.0	28.48	18.8	47.2	1.116	1.051	1.094	.692
	3	202.2	24.65	49.8	152.4	3.036	2.821	2.898	1.715
	4	129.2	24.89	32.2	97.0	1.940	1.813	1.876	1.088
	5	161.3	21.43	34.6	126.7	2.104	2.003	2.066	1.205
	6	171.8	22.61	38.8	133.0	2.383	2.175	2.225	1.264
	7	34.6	27.24	9.4	25.2	.591	.553	.570	.364
	Total	800.3		193.8	606.5	11.741	10.933	11.210	6.635
	Average	133.4	24.21	32.3	101.1	1.957	1.822	1.868	1.106
Water 5 days	8	90.3	20.15	18.2	72.1	1.119	1.026	1.069	.640
	9	37.2	27.33	10.2	27.0	.627	.590	.606	.365
	10	249.4	23.57	58.8	190.6	3.633	3.429	3.512	2.040
	11	74.7	26.57	19.9	54.8	1.216	1.103	1.130	.659
	12	258.0	14.81	38.2	219.8	2.250	2.095	2.178	1.081
	13	52.6	30.23	15.9	36.7	.944	.885	.916	.528
	Total	762.2		161.1	601.1	9.788	9.128	9.411	5.312
	Average	152.5	21.12	32.2	120.2	1.958	1.826	1.882	1.062
Final 5 days	14	128.3	23.09	29.6	98.7	1.790	1.658	1.712	1.042
	15	86.4	24.34	21.0	65.4	1.336	1.241	1.283	.767
	16	206.5	21.56	44.5	162.0	2.800	2.561	2.664	1.555
	17	50.6	11.06	5.6	45.0	.340	.303	.300	.159
	Total	471.8		100.8	371.0	6.265	5.763	5.958	3.523
	Average	157.3	21.36	33.6	123.7	2.088	1.921	1.986	1.174

Subject E

0.2 % HCl soluble Nitrogen	Acid-alc-soluble Nitrogen	Residue Nitrogen	Percentages of Total Fecal Nitrogen Found in					Carbohydrate	Fat
			Bacterial + soluble	Bacterial	0.2 % HCl soluble	Acid-alc soluble	Residue		
0.214	0.131	0.067	90.4	53.7	37.4	22.9	11.7	1.02	2.75
.402	.273	.073	94.2	62.1	36.0	24.5	6.5	2.03	4.28
1.183	.706	.233	92.9	56.5	39.0	23.2	7.7	5.59	10.87
.748	.451	.176	93.5	56.1	38.6	23.3	9.1	3.17	5.90
.861	.489	.174	95.2	57.3	40.9	23.2	8.3	3.73	7.44
.961	.521	.252	91.3	53.1	40.3	21.9	10.6	4.43	8.59
.206	(.080)	.042	93.7	61.5	34.9	(13.5)	7.1	.97	1.97
4.575	2.650	1.016						20.94	41.80
.763	.457	.169	93.1	56.5	39.0	(23.4)	8.7	3.49	6.97
.424	.250	.115	91.7	57.1	37.9	22.4	10.3	2.17	3.17
.241	.143	.050	94.1	58.2	38.5	22.8	8.0	1.06	1.84
1.472	.756	.292	94.4	56.2	40.5	20.8	8.0	7.72	11.35
.471	.285	.103	90.7	54.2	38.8	23.4	8.5	1.52	4.46
1.097	.570	.225	93.1	48.1	48.7	25.3	10.0	6.42	7.33
.389	.213	.077	93.8	55.8	41.2	22.6	8.2	1.23	3.53
4.094	2.216	.861						20.12	31.68
.819	.443	.172	93.3	54.3	41.6	22.6	8.8	4.02	6.34
.670	.389	.189	92.6	58.2	37.4	21.7	10.6	3.07	5.58
.516	.304	.111	92.9	57.4	38.6	22.8	8.3	1.51	3.87
1.109	.607	.250	91.5	55.5	39.6	21.7	8.9	3.06	8.69
.141	.092	.040	89.3	47.0	41.4	27.0	11.8	.43	.82
2.435	1.392	.590						8.07	18.96
.812	.464	.197	92.0	56.2	38.9	22.2	9.4	2.69	6.24

limit for its absorption had been passed. In the case of Subject W in the first experiment there was no evidence of having reached the absorption limit while considerable difficulty was experienced in ingesting and disposing of the large quantity of water. This would again lead to the conclusion that individuality is an important factor.

Protein. A comparison of the data on the excretion of nitrogen in its various forms during the three periods of this experiment allows no conclusions to be drawn. The differences are too small to be significant.

Carbohydrate. The average daily excretion of carbohydrate rose from 3.49 in the preliminary period to 4.02 in the water period, and fell to 2.69 in the final period. Stool 12 weighing 258. grams contained 6.42 grams of carbohydrate and only 38.2 grams of solid matter; there was pronounced evidence of fermentation. It was passed fifteen hours before the usual time and was evidently the result of the intestinal conditions previously mentioned, page 37, to which E was subject at times. A larger amount of undigested material than was usual might therefore be expected, and its appearance could not be attributed to the effect of the water. The fall in excreted carbohydrate during the final period is marked, and shows rather conclusively that the high daily average output during the water period was not due to the fact that water interfered with the digestion of ingested carbohydrate but rather that the unusual finding during the water period may logically be explained as above.

Fat. The data on fat show a decrease in the eccretion of fats during the water period from 6.97 to 6.34 grams per day and the daily average value for the final period, 6.24, is even slightly less than for the water period.

Inferences. The effect of copious water-drinking with meals is seen to be in the same direction when the organism is accustomed to water-drinking as when it is not, except that when water-drinking with meals is habitual the results noted are less striking than otherwise.

The sensitiveness with which the digestion of carbohydrate and especially of fat responds to the influence of dilution is an interesting fact to be observed in all the subjects both under moderate water-drinking and under copious water-drinking. Where the data for protein digestion under different conditions show changes that are insignificant and variable in direction, those on carbohydrate digestion can still be interpreted, while those one fat are still more clear. In artificial digestion experiments fats are often more easily worked with than carbohydrates, and proteins are least satisfactory of all, as far as quantitative results are concerned. The results from investigations involving lipases can probably be relied upon to a greater extent than the results of the action of proteolytic enzymes. It may well be, therefore, that the simplicity of fat cleavage that is observed <u>in vitro</u> when working with lipases taken together with the observation made regarding the satisfactoriness of the fat data in all these experiments points to the fact that the true status of the digestive efficiency of a normal organism under different conditions

can best be learned from the data obtained on fat digestion. It may also be said that the analytical work involved in fat determination by the Kumagawa-Suto method has as much finality and definiteness as the most careful Kjeldahl determination.

Discussion.

Since the same kind of variation but differing in intensity is observed as a result of copious and of moderate water-drinking in the same organism the question arises as to what the effect of water with the meals is, and how the variation in the amounts ingested brings about the changes observed.

In his first experiments on dogs Pavlov 3) found that a large amount of water (500 cc.) caused a flow of gastric juice, while a small amount (150 cc.) in half the cases observed had not the least effect. He states that the important factor is a prolonged and widely spread contact of water with the gastric mucous membrane. This can not be the only factor since the mucosa of the accessory pouch, the secretions of which are the basis for all inferences, is not in contact with the water at all. Its intact nerve and blood supply makes a secondary effect through these channels probable. In any case the contact of the water with the gastric mucous membrane can not be called prolonged, because of the rapid passage of water through the pylorus; this very circumstance, however, may make a large volume of water effective as against a small volume in that the former secures a more widely spread contact than the latter, and perhaps also for a slightly longer period of time.

Observations on human beings with gastric fistulae 29,30,31)

have showed that a purely psychic secretion such as has been noted in dogs is not as pronounced in man as in these animals. A pleasant taste of food in the mouth caused a flow of gastric juice in some instances, but whether, in general, such a secretion of gastric juice in man arises indirectly through stimulation carried by the blood or by the nerves or whether it is due directly to the contact of substances with the mucous membrane of the stomach is uncertain. Considered in the light of the findings of Pavlov 3) and of Foster and Lambert 4) the observations on men in these experiments upon water-drinking indicate that a large volume of water brings about an effect which is not observed, at least in not as definite a way, when a small volume is taken. The effect is a better digestion and a more complete utilization of the food-stuffs.

There is one objection to the conclusion that this is caused by water-drinking. It has frequently been observed in experiments on men that the prolonged administration of a given diet causes the enzyme content of the digestive juices so to change as to be best adapted to digesting the food. It might be argued therefore that although the food was as well digested during the latter part of these experiments as in the beginning, this was as a result of adaptation which counteracted the undesirable effects of water-drinking. A comparison of the data of the final periods with those of the water periods is sufficient to show that the withdrawal of water was accompanied by a pronounced change in favor of the water-drinking, or by no appreciable change in digestibility and utilization.

Any supposed effect of adaptation is also counterbalanced

by the effect of loss of appetite due to the monotony of the diet. London and Pewsner 32) found that in dogs the stomach contents were more rapidly passed on to the duodenum when the factor of appetite was present than when it was absent. They conclude that the larger amount of secretion, that is, the appetite juice, was the cause. If there is any increased efficiency in "appetite" juice over the ordinary secretion in man then the digestive power of all the juices is at least not increased by the factor of appetite after partaking of over one hundred meals that were absolutely uniform in the kind and quantity of food they contained.

It seems clear that the better digestion and utilization of food observed when water is taken with it is due alone to the influence of the water. The specific action of water in the digestive tract, the effects of which cause better digestion of the food is (1) the stimulation to the flow of gastric juice and independently, of pancreatic juice; (2) the increase in acidity of the gastric juice and as a result of more strongly acid chyme in the duodenum an increased flow of pancreatic juice and of bile; (3) heightened peristalsis due to increased volume of the intestinal contents; (4) more complete hydrolysis and absorption due to increased dilution: (5) increased blood pressure due to absorbed water, and consequently a stronger and more rapid heart action.

The larger volume which the food assumes by the addition of water and increased amounts of gastric juice must cause a portion of the food, perhaps all of it, to leave the stomach sooner than under ordinary conditions. Increased acidity also causes the pyloric sphincter to open earlier in the digestive process than usual. It

might be argued that this shortening of the time in which gastric digestion can go on is undesirable. The question is, therefore, what part does the stomach play in digestion and absorption.

Of all the food-stuffs carbohydrates are normally the first to leave the stomach and a shortening of the time of their sojourn there might mean incomplete hydrolysis especially of starch. In experiments on dogs London and Polovzova 33) have shown that sucrose and erythrodextrin alone suffer a slight hydrolysis in the stomach, due not to enzymes but to hydrochloric acid, and that under no conditions are carbohydrates absorbed in the stomach. In the duodenum hydrolytic cleavage is very extensive but absorption does not begin until the upper ileum is reached where the greater portion of carbohydrate is absorbed. The great importance of the duodenal juices in carbohydrate digestion is hereby emphacized.

Von Mering 34) concluded from some of his observations that the various sugars could be absorbed in the stomach, absorption being dependent upon the concentration of the solution; that below 5% dextrose was not sensibly absorbed.

London and Polovzova 35) found that protein was not absorbed in the stomach. Examination of stomach contents revealed the fact 36) that peptones, peptides and amino substances may be absorbed; while it is shown that the enzymes of the stomach have the ability completely to hydrolyze proteins to these end-products, yet it is also shown that the length of time which pepsin requires to bring this about is far in excess of the time during which protein remains in the stomach.

The cleavage of fat by gastric lipase is very minimal in the

normal acid reaction of the stomach, except when the fats are in the form of a natural emulsion. London and Versilova 37) showed that the cleavage of fat fed in such a form (egg-yolk) rose as high as 32% in the stomach; absorption of this fat, however, was found not to take place until the ileum was reached. Ordinarily natural fat emulsions are not a large proportion of the normal diet: milk is the only usual one. Acids also tend to destroy emulsions. It may be said then that, as a rule, emulsification , saponification, and absorption of fats do not take place to any extent until the fats reach the alkaline or neutral medium of the intestine and the biliary secretion is poured out upon them.

The importance of the stomach in protein assimilation has been emphacized recently by Carrel, Meyer and Levene 38) who showed that after removal of the larger part of the small intestine although the absorption of ingested protein is diminished, the rate of assimilation and retention of the absorbed protein follows the same course as in normal animals. London and Dmitriev 39) showed that removal of the small intestine in a dog results in the death of the animal in about five weeks. Ordinarily if as much as seven eighths of the small intestine is removed carbohydrate and especially protein assimilation rapidly return to normal but not so with fat absorption.

The experiments which have been made to determine the impor - ance of the stomach as an absorptive organ are not free from criticism 40). They seem to indicate however that a small percent, perhaps, of the protein in an ordinary meal may be absorbed by the gastric mucous membrane. Taylor 41) states that the important functions of the stomach physiologically and pathologically are

the motor functions; the lesser functions are the chemical or digestive functions.

As far as absorption is concerned, therefore, a shortening of the time that the food-stuffs spend in the stomach may be of little or no importance. To be set over against a possible insufficient digestion here for lack of time is the increased hydrogen ion content of the gastric juice as a result of which it is more active, and also the stimulation to greater activity of the digestive juices appearing in the duodenum and below it.

The results of these experiments on water-drinking with meals show that the latter are the more important considerations. If, wh n water is taken with it the ingested food is subjected for a less time to gastric digestion, this has no detrimental effect, for the increased efficiency of intestinal digestion and absorption more than compensate for the other.

The more complete utilization of the food as observed during water-drinking involves not only better digestion but better absorption. The phenomena of absorption still lack a unifying physical explanation. Osmosis and selective action of membranes are the basis for some of the explanations offered. The epithelial cells of the alimentary tract obey the ordinary laws governing the osmotic absorption of water only when exposed to great and sudden changes by being flooded with solutions of very high or very low osmotic pressures. Nor are the intestinal epithelia true semi-permeable membranes; their action is rather a selective one. The fact that protoplasm as well as some of the end-products of digestion are colloidal in nature furnishes another basis for explaining

certain observations on absorption, namely by the change in the affinity of colloids for water.

Fischer gives a probable explanation 42) for the absorption of hypertonic, hypotonic and isotonic solutions from the intestine. If, as a result of dilution the contents of the intestine are hypotonic with respect to the blood, water will be absorbed very readily by the blood until as a result of its own dilution and of the increased concentration of the intestinal contents the dissolved substances in the latter are placed in a position to diffuse into the blood. The osmotic pressure of the solution in the intestine is thereby again lowered and water is absorbed from the blood. Were the relations as simple as this, absorption would cease when the osmotic pressure of the contents of the intestine was the same as that of the blood. However, because of the presence in the blood of colloids which have no great osmotic pressure but nevertheless exert some, it is held that after all other osmotic differences on both sides of the diffusing membrane have been equalized an excess of osmotic pressure due to the colloids must still remain on the side of the blood, and since this can not be equalized by diffusion from the blood water will pass out from the intestine rendering its contents hypertonic. Solutes can then diffuse, and thus gradually the reaction goes to completion.

According to this theory rapidity of absorption of digestion products depends to some extent upon their physical condition; the more completely they are broken down, that is, the better they are digested the less is the proportion of colloids to crystalloids in the final material to be absorbed, and therefore the more rapid the

absorption.

Some experimental work has been on the absorption of food-stuffs by living membranes. Zunz 43) in experiments on dogs upon protein digestion and absorption in the stomach and small intestine <u>in situ</u> has shown that the osmotic pressure of the solutions of protein introduced scarcely changes in the stomach when this is tied off but in the small intestine it tends toward that of the blood and usually becomes lower than this. Here also the concentration of the solutions becomes lower than that of the blood. Surface tension is lower than that of the blood in both the stomach and intestine. With low proteose content the surface tension decreases in both regions. In the intestine, Zunz concludes, the digestive processes tend to bring the concentration, osmotic pressure and surface tension of the contents to the optimum for absorption. The organism itself seems to strive to secure a dilution of the products of digestion such that they can be most readily and completely absorbed.

London and Polovzova 44) have made similar experiments with solutions of dextrose on dogs with intestinal fistulas and the following are their findings. With increasing concentrations of the dextrose solutions introduced absorption of water in the intestine diminishes progressively. With higher concentrations a diluting secretion begins to flow from the wall of the intestine; its amount runs parallel with increasing concentration of the dextrose solution, and at its maximum it may amount to one-half the total quantity of blood in the animal. By this dilution and also by absorption of sugar the concentration of the solution is brought down to 6-8%, a dilution at which absorption takes place very readi-

ly in the lower intestinal tract. The secretion of the diluting fluid begins with the coming in of the first dextrose solution and continues fairly uniformly. Dilute dextrose solutions seem better adapted to absorption that concentrated ones. In the lower portions of the intestinal tract the concentration tends toward a value that is lower than isotonic. The diluting secretion has a small amount of nitrogen (0.1%) and possesses a kinase, so that in part at least it represents an increased intestinal secretion. For concentrated solutions absorption seems to take place in two stages; in the proximal portion of the intestine the proper dilution is reached, in the distal portion absorption takes place. The intestinal wall differs from the stomach wall in that the latter does not dilute concentrated solutions. The absorption of water and of dissolved substances must be considered as two independent and distinct processes, brought about by different factors. The ability to regulate automatically the concentration of substances to be absorbed is believed to be a part of the function of the digestive juices.

Applying these findings to the experiments on water-drinking with meals the explanation for the more complete digestion and absorption of the foods during the period of water ingestion is facilitated. Increased dilution is the effective factor. While it would seem in these experiments that the water taken with a given meal is voided in the urine before the bulk of the food material of that meal has reached the intestine, nevertheless some of the food must be carried along with the water. And further, since absorption is going on more or less continuously in the intestine, the water taken with one meal aids in diluting the products of the previous

meal which are in the intestine. Not only is enzyme action more complete in dilute solutions but such solutions are also better adapted to absorption. When the solutions to be absorbed are not dilute the organism must first make them so by pouring out a diluting secretion; if they have been made dilute the organism is spared this task.

Applying Foster and Lambert's reasoning, page 4, on needless expenditure of energy, a so-called "form of extravagance" accompanying the increased flow of gastric juice brought about by water-drinking, a similar form of extravagance may be said to be caused in the intestine by insufficient water ingestion with meals. If there is a loss in energy in the increased flow of gastric juice by water-drinking, this is more than compenstaed by better digestion and absorption of food in the intestine, while the needless energy used in preparing a diluting secretion for food which is too concentrated is a direct loss uncompensated by any subsequent factors making for better utilization of the food. The preservation of the digestive efficiency of the intestine is of much greater importance than that of the stomach, since it is probable that the main offices of the stomach are not those of a digestive nature.

Summary and Conclusions.

(1) It has been shown that the drinking of large amounts of water with meals by men brought to nitrogen equilibrium on a uniform diet brought about a decreased average daily excretion of feces, of fecal dry matter, and of fecal water.

(2) Detailed examination of the feces showed that the decrease in

the amount of feces during the period of water-drinking was due to (a) decreased elimination of fecal nitrogen, of bacterial nitrogen, of soluble nitrogen, and of residue and undigested nitrogen; (b) decreased elimination of carbohydrate; (c) decreased elimination of fat.

(3) These facts indicate that when large amounts of water (1000 cc.) are taken with meals the digestion and utilization of protein, fat and carbohydrate are more perfect and complete than when water is taken sparingly with meals.

(4) The decreased elimination of nitrogen, fat, and carbohydrate in the feces was evident for a number of days after water ceased to be taken in large amounts with meals, indicating that the beneficial influence of water was not temporary but was more or less permanent.

(5) A slight gain in weight accompanied the water-drinking, and this gain was not subsequently lost.

(6) A moderate quantity of water (500 cc.) with meals had the same effect as a large amount, except that the beneficial results were not as pronounced. Better digestion and absorption, especially of carbohydrates and fats, was evident.

(7) After several months of moderate water-drinking with meals a pronounced improvement in the digestibility of all the food-stuffs was observed, the average percentage utilization being 93.3% at the start and after three months 95.5% .

(8) The beneficial effects resulting from the ingestion of water with meals are due to the stimulatory action of water upon the digestive secretions, to the increased dilution which facilitates enzyme action and materially aids in absorption, and to a conserva-

tion of the intestinal energy involved in the secretion of a diluting fluid which is necessary when insufficient water is ingested.

(9) Many desirable and no undesirable effects were obtained by the use of water with meals, the more water used the more pronounced were the benefits.

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